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Jet spray tool

FIELD OF THE INVENTION

The present invention relates to a jet spray tool for treating surfaces, especially cleaning surfaces using a carbon dioxide snow stream.

BACKGROUND OF THE INVENTION

Carbon dioxide snow jets or jets of pellets are known as cleaning means for surfaces, for example before further surface treatment. For example, such a system is disclosed in International patent application WO 01/76778 by Nielsen.

In International patent application WO 00/74897 by Werner and Zorn, a jet spray tool with a concentric dual nozzle system is disclosed. The dual nozzle system produces a supersonic stream of support gas for the ejected carbon dioxide snow. This system is complicated and expensive to produce.

Other complicated systems are disclosed in European patent application EP 332 356 by Kozo et al. and Japanese patent application JP 54015623 with publication no. JP 55106538 by Yamauchi Hiroshi.

DESCRIPTION / SUMMARY OF THE INVENTION

It is the object of the invention to provide a novel jet spray tool which is easy and cheap to produce and yet reliable to use.

This object is achieved with a jet spray tool for frozen carbon dioxide particles comprising a supply unit containing carbon dioxide gas under high pressure, for example 40-60 bar, a jet nozzle connected to the supply unit for receiving pressurised carbon dioxide gas from the supply unit and for producing a jet of frozen carbon dioxide particles due to the expansion of the gas when exiting the nozzle, and a connection be-

tween the supply unit and the jet nozzle for transporting the pressurised carbon dioxide gas from the supply unit to the jet nozzle.

In the above stated prior art, liquid carbon dioxide is supplied to the carbon dioxide snow producing nozzle. However, this has led to rather complicated arrangements.

In connection with the invention, it has surprisingly turned out, that carbon dioxide in gas form successfully can be used to produce frozen carbon dioxide at a nozzle due to the expansion of the pressurised gas. Typically such pressure is 40-60 atmospheres.

As experiments have indicated, an arrangement according to the invention, as described below, results in formation of a fast jet of carbon frozen dioxide particles leaving the nozzle. This jet behaves differently than typical snow jets known from arrangements, where liquid carbon dioxide is used. The effect has not yet been fully understood, but there are indications of frozen carbon particles in a physical/chemical phase that has not yet been observed for this kind of jet formation but which has proved to be very efficient for cleaning surfaces.

In practice, the supply unit may contain carbon dioxide gas and carbon dioxide liquid. However, to assure gas extraction and not liquid extraction, the connection is connected to the supply unit above the carbon dioxide liquid level in the supply unit. Thus, the connection may be connected to the supply unit at the uppermost point of it.

In order to control the release of snow from the nozzle, a valve is located between the supply unit and the nozzle.

If the length of the connection is very long, it takes a substantial length of time and waste of carbon dioxide, until a carbon dioxide particle jet forms at the nozzle. This is a disadvantage for intermitted operation of a jet spray nozzle. Therefore, the supply unit should be near to the nozzle, for example at a distance less than 500 mm, such that the length of the connection is short. In a practical embodiment, the applied distance between the extraction point of the supply unit and the nozzle has been set to 70

mm, which has been proven to be particularly useful. However, a length of less than 200 mm can in certain instances be sufficient.

The rapid transport of gas from the intermediate chamber to the nozzle due to the short distance of the connection cools the nozzle so fast and efficient that a jet can be formed within less than a second after opening of the valve. Therefore, this system is easy to construct, cheap to produce and yet very reliable and precise even for intermittent jet application.

As a supply unit, a carbon dioxide bottle or tank can be used directly connected to the nozzle at a short distance. However, due to the short length of the connection between the supply and the nozzle, a large tank is disadvantageous near the nozzle. Therefore, in a further embodiment, the carbon dioxide tank may be located at a larger distance and be connected to the supply unit for supply of carbon dioxide from the tank to the supply unit as an intermediate chamber close to the jet nozzle. This is especially useful where the distance between the carbon dioxide tank and the supply unit is much longer than the distance between the supply unit and the jet nozzle, for example more than an order of magnitude larger.

In experiments for cleaning surface, the internal volume of the intermediate chamber was about 50 cubic centimetres, and depending of the need, it is proposed to use a volume of the order of between 5 ccm and 500 ccm.

In the supply unit as an intermediate chamber, carbon dioxide is received and stored before further use at the nozzle. There may be stored carbon dioxide liquid in the intermediate chamber together with carbon dioxide gas for extraction.

It may in some circumstances be an advantage that the intermediate chamber and the gas therein are cooled during the storage time, which in most circumstances is relatively short. For this cooling, the intermediate chamber has an opening into atmosphere for exhaust of carbon dioxide, which causes cooling.

A typical nozzle that has been used with success is tubular and comprises a lateral groove across the exit hole at the front end of the nozzle.

As an extra feature, the jet spray tool according to the invention may comprise precooling arrangement for precooling the jet nozzle before ejection of a jet of frozen carbon dioxide particles, for example in the form of snow, from the nozzle. Such a precooling can be accomplished by, for instance, by a Peltier cooling element in thermal contact with the nozzle or by a container with liquid Helium in thermal contact with at least part of the nozzle. In this case, the nozzle can be precooled to a temperature of at least below ÷40°C and preferably to the boiling temperature of liquid carbon dioxide.

SHORT DESCRIPTION OF THE DRAWINGS

The invention will be explained in more detail with reference to the drawing, where

FIG. 1 is a diagram of the jet spray system with the spray tool,

FIG. 2 is a sketch of a possible embodiment of the nozzle,

FIG. 3 is a micrograph of an aluminium surface,

FIG. 4 shows two micrographs in connection with a first cleaning process of an aluminium surface using a slit nozzle with 0.8 mm size,

FIG. 5 shows two micrographs in connection with a second cleaning process of an aluminium surface using a slit nozzle with 1.1 mm size,

FIG. 6 shows two micrographs in connection with a third cleaning process of an aluminium surface using a nozzle with a round exit hole with a diameter of 1.2 mm.

DETAILED DESCRIPTION / PREFERRED EMBODIMENT

Fig. 1 is a diagram of the jet spray system with a jet spray tool according to the invention. The jet spray system 1 comprises a storage tank 2 for carbon dioxide liquid and gas, typically at a pressure of 40-60 atmospheres. The storage tank 2 is connected to a nozzle arrangement 9 with a nozzle 10, through which a jet of frozen carbon dioxide particles 11 is ejected when carbon dioxide gas is supplied under high pressure. The

connection 4, 6, 8 between the storage tank 2 and the nozzle 10 can be accomplished by stiff and/or flexible tubing that generally is used for this kind of arrangements. The carbon dioxide supply from the storage tank can be controlled by a valve 3.

Inserted between the storage tank 2 and the nozzle 10 is an intermediate chamber 5, where carbon dioxide supplied from the storage tank 2 can be stored for rapid extraction. From the intermediate chamber, carbon dioxide gas can be supplied to the nozzle through the tubing 6, 8 when valve 7 is opened, where the extraction of carbon dioxide from the intermediate chamber 5 through the tubing 6 is above the liquid level 18 in the intermediate chamber in order to assure gas extraction. Alternatively, the extraction can be from the top of the intermediate chamber in order always to assure gas extraction. As the intermediate chamber is only 70 mm from the nozzle, the supply of carbon dioxide gas to the nozzle from the intermediate chamber 5 is rapid enough to cause a fast cooling of the nozzle resulting in a formation of a carbon dioxide particle jet after a very short initial phase of cooling of less than a second. This is very suited for sequential spraying with time scales in the order of few seconds. The intermediate chamber 5 further comprises an opening 17 into atmosphere.

A nozzle arrangement 9 that can be used in a system according to the invention is illustrated in Fig. 2. The nozzle arrangement 9 is connected to the tubing 8 by a standard connection, for example a threaded fitting 13. The nozzle arrangement 9 comprises a tubular nozzle 10 with a simple jet exit hole 16 inserted into a nozzle holder 14 fastened to the tube fitting 13. This nozzle arrangement 9 with the nozzle 10 is very simple in nature, though still providing a satisfactory jet 11 of carbon dioxide particles.

An improvement of the jet formation has been observed for nozzles 10 that are provided with a lateral groove 15 across the front end of the nozzle 10 with the ejection hole 16, which is shown in an enlarged head-on perspective in Fig. 2b.

In the following, some experimental results are presented which are achieved with an arrangement according to the invention.

In FIG. 3, a micrograph of an aluminium surface is shown without a surface treatment with a jet tool. The width of the image is 1 micrometer. Three pieces of aluminium have been treated with three different jet tool nozzles in an arrangement according to the invention. The results are shown in FIG. 4, 5 and 6 for three different dies. For each of FIG. 4, 5, and 6, the right image shows an untreated part of the surface and the left image shows a corresponding surface treated with a carbon dioxide jet according to the invention. Beware that the width of the right images is 1 micrometer, whereas the left images have a width of 0.5 micrometer.

The dies used for FIG. 4 and 5 had slit formed nozzle holes with widths of 0.8 and 1.1 mm, respectively, whereas the die used for FIG. 6 had a circular nozzle exit hole with a diameter of 1.2 mm. Useful nozzle exit hole sizes have been tested primarily in the range of 0.8 to 3 mm. Nozzles with hole diameters of up to 10 mm have been used, however, the amount of carbon dioxide for a jet cleaning process increases largely for such large nozzles.

The form of the nozzle exit hole or holes depend on the desired use. For example, a nozzle has been used with a central hole formed as a slit and two side round holes. The distances from the nozzle to the probe were typically 15-25 mm and the gas pressure 60 bar.

As can be seen from FIG. 4, 5 and 6 in mutual comparison, the result in FIG. 6 is more pronounced than the other two results. As the crystals on the aluminium surface were distinctively smaller, a higher surface tension was achieved resulting in a more smooth glue layer on the surface.

In the experiment, where aluminium pieces afterwards were glued together, it turned out that the strength of the glue after the jet tool treatment as shown in FIG. 6 was comparable to the strength of glue after initial cleaning with isopropanol (IPA) which is the normal way used in industry. For steel and aluminium surfaces, strengths of more than 19 MPa were achieved. This is a great advantage, because cleaning with

alcohol implies high costs and is environmentally disadvantageous. Thus, by the invention, a simple way with low costs has been found to substitute the undesired use of IPA in cleaning processes of surfaces, for example metal surfaces such as aluminium surfaces or steel surfaces.

Cleaning with IPA resulted in surfaces with approximately 2-3% of chemical remnants on the surface. In contrast, the cleaning with the carbon dioxide particle jet yielded a much cleaner surface, where the amount of remnants was less than 0.1% making this method highly useful for surfaces where the cleaning is critical.

The jet from the nozzle has been observed to behave differently than normal snow jets from prior art nozzles. Also, supply of liquid carbon dioxide to the nozzle did not lead to successful results. This indicates that the expansion of the highly pressurised gas leads to a special phase of carbon dioxide which has not yet been completely understood.

A nozzle according to the invention may comprise a central stop in front of the nozzle exit hole. This would result in a hollow conical jet which is suited for cleaning of surfaces, where certain areas of the surface should not be hit by the jet. Such surfaces may be printed circuit boards with delicate electronic components.